

3 1761 12064407 5

Prepared testimony of Mr. C.P. Lewis

Physical aspects of the Beaufort Sea coast

February 5, 1976

MACKENZIE RALLY PIPE LINE INDUSTRY
EXHIBIT NO. 467 A E Feb. 13/76

Invent. nwt.
PUT IN C.O.P.G.



Digitized by the Internet Archive
in 2025 with funding from
University of Toronto

<https://archive.org/details/31761120644075>

PHYSICAL ASPECTS OF THE BEAUFORT

SEA COAST

Introduction

1. My intention is to discuss those physical aspects of the Beaufort Sea coast which might be important in any plan to develop hydrocarbon resources offshore.
2. In this development I include both construction and operational requirements: for example, pipelines coming ashore, harbour development, staging facilities, and the coarse aggregate mining necessary for their construction.
3. Because any pipeline from offshore will probably need to move crude oil as well as gas, the consequences of an oil spill are also relevant.

The Coastal Zone

4. For the purposes of this discussion I have defined the coastal zone as the area between the highest storm tide line on land (about 10 ft. above mean sea level) and the 30 ft. water depth (commonly assumed to be the seaward limit of bottom material movement by waves).
5. The effects of development in this zone are of particular importance because it contains large bird and fish populations and is the part of the Beaufort Sea most used by man at the present time.

Slide 1

(Map of Southern Canadian Beaufort Sea Coast)

6. The length of coast with which I am personally familiar and which I will consider today extends from the Alaskan border to the eastern end of the Tuk Peninsula at Cape Dalhousie.
7. The topics I intend to cover include: the effects of an Arctic environment, nearshore water circulation, storm surges, coastal landforms and materials, and coastal stability - all set in the context of the influence they should

- have on the type, extent and location of facilities associated with hydrocarbon resource development.

Effects of an Arctic Environment

8. It is, I think, important to realize that the area under discussion is, in some senses, not "true Arctic" in nature. The open water season, particularly where the influence of the Mackenzie River is felt, is long by arctic standards. For 3 to 4 months a year there can be tens or even hundreds of miles of open water on which wind can generate waves to cut back the coast.
9. The response of coastal materials to wave attack is, however, "true Arctic" in nature. Frozen ground plays an important role in the coastal zone. Unlike areas such as the Canadian west coast, coastal materials along the Beaufort Sea are unconsolidated. No bedrock is present. But because this unconsolidated material is permanently frozen and contains considerable ground ice in many locations, both the nature and rates of coastal change differ considerably from what they might be in a more temperate climatic setting.
10. The net effect of these factors is complex. Because of the long open water season and the unconsolidated nature of the coastal materials, the entire coastline is retreating. The rate of retreat, however, is controlled to a large extent by the nature, amount and location of ground ice in the sediments. Where the coast is composed of coarse sands and gravels, the frozen nature of the materials may slow down wave erosion. But where large amounts of ground ice are present, retreat will be even more rapid than if the materials were unfrozen.
11. From the development point of view, these factors are critical. Facilities must contend with both an active summer marine environment and the presence of frozen ground - a situation for which there is no parallel in past hydrocarbon development.

Nearshore Water Movement

12. The patterns of water movement in the coastal zone are quite different from the offshore circulation discussed by Mr. Herlinveaux. As you will see, they are very relevant to the effect an oil spill might have on the coast.

Slide 2

(Topkak spit)

13. Because the nature of the Beaufort Sea coast has been conditioned by the relatively rapid erosion and redistribution of the materials of which it is composed, the position and orientation of resultant depositional features, like this spit just north of Tuktoyaktuk, can be used to infer the dominant direction of sediment movement and thus the dominant longshore current direction at any location where they are present. ,
14. Please note that I use the term dominant direction. I don't mean to imply that this is the only direction in which nearshore currents can flow. It is probable, though, that the dominant directions are those in which oil would move during major sediment transport events, that is to say during summer and fall storms when low lying areas could be flooded by the sea level rises associated with strong onshore winds, and thus would be open to inundation by oil.

Slide 3

(Map of Southern Canadian Beaufort Sea Coast)

15. I have plotted dominant current directions for the Beaufort Coast on this map as black arrows and, on the basis of these directions, I've divided the coast into segments. Each segment consists of a sediment sink toward which sediment is being moved and the contributing source area. The segment boundaries are indicated by the yellow lines on the map and each segment (there are 11 in all) is labelled by the black letters on yellow backgrounds.
16. The importance of this segmented circulation pattern is that, particularly during storm events, oil reaching the nearshore zone will tend to remain within the coastal segments I have identified and to move toward the sediment sink of each segment.
17. It might appear attractive, as well, to locate shore installations having a high potential for spillage in the sink areas. Unfortunately, however, because these areas are sediment as well as potential oil sinks, they tend to be very shallow and to contain spits and lagoons that make them favorite locations for fish and shore bird populations.

Storm Surges

18. I have already mentioned sea level rises associated with strong onshore winds during summer and fall storms; these rises are sometimes called storm surges.
19. Based on an examination of tide gauge records at Tuk, Dr. R.F. Henry of Ocean and Aquatic Affairs, DOE identified 22 surges which caused water level rises of more than 3 ft. between 1962 and 1973, including 2 which caused rises of more than 6 ft. A September 1970 storm, for which no tide gauge data is available, may have caused a rise of as much as 10 ft. at Tuk. *by a 10 ft. rise*
20. These surges are of importance for several reasons: first, waves associated with them cause much of the erosion and longshore sediment movement which occurs along the Beaufort Sea coast, a topic I will discuss later; and, second, they lead to the inundation of low-lying coastal areas by sea water, water which might contain oil in the event of a spill.

Slide 4

(Kay Point Spit; June 21, 1975)

21. This view is of Kay Point spit on the Yukon coast. The spit is about 3 miles long and its crest is about 3 ft. above normal mean sea level.

Slide 5

(Kay Point Spit; Aug. 10, 1975)

22. This view is identical to the last one, but taken during a relatively minor storm surge which occurred in August 1975.

Slide 6

(Map of Southern Canadian Beaufort Sea Coast)

23. Of even greater extent than the spits, bars and beaches are the low lying delta areas of the Beaufort Sea coast, all major wildfowl nesting and staging areas, which could be inundated by a storm surge and by oil or other pollutants contained in the water.

24. Driftwood lines on the Mackenzie delta indicate that the outer delta could be inundated by an extreme surge as far south as the lower green line on this slide, a line which represents the location downstream from which channel banks, the highest parts of the delta plain, are lower than 3 m. (10 ft.).
25. This is an area of almost 1500 sq. mi., which, if it were square, would have sides almost 40 miles long. About 20% of the area is covered by shallow lakes in which pollutants could be dropped and, of this area, almost 30% or 86 sq. mi. is connected by channels which eventually reach the sea. Pollutants could be carried into this type of lake even by surges which were not high enough to flood the delta surface.
26. Exactly how far up delta sea water might penetrate during a surge is dependent upon the influence of river flow as well as upon surge flooding. To my knowledge no research has been undertaken into water circulation patterns over flooded areas of the delta but Dr. Henry's storm surge studies suggest the possibility that sea water and associated pollutants might be drawn in on the Shallow Bay side and river water diverted out East Channel.

Coastal Landforms and Coastal Materials.

27. Let us move now to a discussion of the major landform types found along the Beaufort Sea coast and of the importance of their nature to development.
28. Within each of the coastal segments I have defined, one or more of the following types of landform dominate the coastline:
- a. Steep cliffs, often containing significant amounts of ground ice, and fronted by narrow beaches;
 - b. Thermokarst lakes breached by coastal erosion;
 - c. Spits and barriers up to 8 mi. in length and several hundred yards wide; and lastly
 - d. River deltas, particularly that of the Mackenzie, one of the largest deltas in the world.

A. Coastal cliffs

29. Of these landforms types, coastal cliffs occupy the largest portion of shoreline in all coastal segments except for the modern Mackenzie delta and the eastern end of the Tuk Peninsula.
30. High and steep cliffs are more common along the Yukon coast than along the lower-lying Tuk Peninsula where a relatively small offshore gradient decreases the effectiveness of wave erosion.
31. The cliff form is largely a function of the materials of which it is composed. Gravel and sand dominate along the Yukon shoreline but layers of silt and clay are common. Gravel is also common along the Tuk peninsula west of Tuk, but sands and silts prevail to the east.

Slide 7

(Sand bluffs at the mouth of East Channel)

32. Where the material is coarse, cliffs tend to be steep but not vertical, like this sand bluff near Kittigazuit at the mouth of East Channel,

Slide 8

(Cliff at Tuktoyaktuk)

or the sandy gravel cliff at Tuk itself.

Slide 9

(Cliff at Running River mouth)

They may even be vegetated like this one near Shingle Point on the Yukon coast.

Slide 10

(Vertical bluffs at Kay Point)

33. Where the material is fine-grained, on the other hand, the cliffs will be vertical like this one near Kay Point.

Slide 11

(Multi-cyclic ground ice slump area near Tuktoyaktuk)

and if the fine-grained material contains large thicknesses of massive ground ice, ground ice slumps like this one just west of Tuk,

Slide 12

(Exposed massive ice in ground ice slump of Kay Point)

or this one at Kay Point, will develop. The banded material in the centre of this slide is almost pure ice.

34. These cliffed areas may seem desirable as locations for harbours, staging areas etc. because their tops are well above storm surge levels, water depths offshore from them are usually relatively deep, and, if the cliff material is coarse, a suitable source of construction material is close at hand.
35. But the nature of the cliff material is critical. The most ideal location for a deep water port along the southern Beaufort Sea coast might seem to be in the area of Babbage Bight just east of Kay Point because water depths close to shore are deep. The cliffs in this area, however, are fine-grained and contain considerable massive ice. Vertical bluffs and ground ice slumps predominate. Hardly an ideal location for land facilities associated with a harbour.
36. The presence of frozen ground and massive ice is also relevant to any pipelines which might come ashore in cliffed areas.

Slide 13

(Undercut bluffs at Kay Point)

In areas like this one near Kay Point massive ice bodies extend below sea level and out under the shallow water near shore. Wave erosion during the August 1975 storm I mentioned previously cut a niche at the base of the cliff and exposed the ice behind. This, incidentally, is exactly the situation which exists along the cliffs which front Tuktoyaktuk and is the major reason why it will be so difficult to stabilize the cliffs there. A hot oil pipeline would be subject to failure under these conditions.

B. Thermokarst lakes

37. In addition to the coastal cliff areas, there is a second type of coastline in the southern Beaufort Sea which is basically erosional in nature.

Slide 14

(Phillips Island photomosaic)

This photomosaic is typical of large parts of the coast along the Tuk Peninsula, particularly east of McKinley Bay.

38. At first glance the coastline appears drowned but, in fact, its outline reflects the breaching by coastal erosion of the lakes which cover much of the Peninsula. These lakes are commonly thermokarst in origin, resulting from ponding and resultant differential melting of excess ice in the sands and silts which form their boundaries.
39. Breaching leads to at least partial draining of the lakes and, if this drop in water level is sufficient to enable the lake to freeze to the bottom in winter, to the formation of pingos. The "two-pingo lake" on this slide is about 3 ft. deep.
40. As erosion continues, the former lake area is deepened, partly because of wave action and partly because of continued melting of excess ice in the sediments. The area between the barrier bar and the "two pingo lake" on this slide is flat-bottomed and about 10 ft. deep but sub-bottom, generally less than 13 ft. beneath represent the boundary between recent wave-deposited sediments and the older and perhaps still frozen coastal plain deposits beneath.
41. In any case, a newly breached lake provides an excellent trap for an oil spill. Oil could be carried into a lake during normal flood tides or storm surges.

Slide 15

(Two-Pingo Lake)

Granted it might be pulled out again by ebb currents but, unfortunately, the

eastern end of the Tuk Peninsula, where breached lakes are most numerous, is also the only coastal segment, except for river deltas, which contains extensive tidal flats. This slide shows exposed tidal flats in and near the "two-pingo lake" of the last photograph.

C. Spits and barriers

42. Let us turn now to the depositional features found along the Beaufort Sea coast.

Slide 16

(Warren Point barrier)

Spits, like the ones I have already shown you at Topkak and Kay Points, and barriers, like this one at Warren Point on the Tuk Peninsula, front significant portions of most of the coastal segments I have identified.

43. They are particularly extensive near Herschel Island on the Yukon coast, around the old islands (Pelly, Hooper etc.) which front the eastern Mackenzie delta, and from Warren Point east on the Tuk Peninsula. In these areas they reach lengths of more than 8 mi. and widths in excess of 200 yd.
44. As I have already mentioned, they lie, in their entirety, below the highest storm tide line and thus are susceptible, at any time, to inundation by oil. As well, the shallow lagoons behind them could function in much the same way as thermokarst lakes and act as traps for oil.
45. The size of spits and barriers is a function of both offshore gradient and sediment supply. They are largest where offshore water depths are small as they are off the Mackenzie delta and the Tuk Peninsula, or where the supply of sediment is large as it is in the Herschel Island area where material from the Eirth and Malcolm rivers is added to that supplied by cliff erosion.
46. Their height and cross-sectional form, on the other hand, are at least partially

dependent on sediment size.

Slide 17

(Numaluk spit, proximal end)

The sandy-gravel spits and barriers of the Yukon coast and west of Tuktoyaktuk on the Tuk Peninsula tend to be higher and narrower than pure sand features east of Tuktoyaktuk. This portion of Numaluk spit near Herschel Island rises over 7 ft. above sea level,

Slide 18

(Atkinson spit, proximal end)

whereas this sand spit at Atkinson Point reaches a maximum elevation of less than 3 ft.

47. The gravel in coastal beaches, spits and bars and their easy accessibility from the sea makes them attractive sources for borrow materials. They are not thick, however. Both drilling and low-frequency sub-bottom echo sounding suggest that significant gravel deposits seldom extend more than 15-20 ft. below the surface, either on land or near shore.

d. River deltas

48. Deltas represent the continuing ability of a river to supply and deposit sediment more rapidly than it can be removed by sea waves and currents. In the case of the Mackenzie delta, the ability of the Mackenzie River to dominate the Beaufort Sea has led to the development of a gently sloping delta plain of over 8000 sq. mi. in surface.
49. Of this surface area, as I have already mentioned, about 1500 sq. mi. may be subject to inundation by storm surges and thus is properly part of the coastal zone. But even this outer delta is river dominated. The clays, silts and fine sands of which it is composed are almost entirely riverine in origin. The manner in which these sediments are deposited, however, is greatly influenced by coastal processes.

Slide 19

(Outer Mackenzie delta)

50. The most important features of the outer delta plain are the shallow, wide distributary channels; the low, flat vegetated plains which separate the channels; and the lakes which dot the plains. This slide, looking south from the shoreline, includes examples of each. Except for the lakes, the pattern you see is common on most fine-grained deltas in the world.
51. The myriad of lakes on the Mackenzie delta plain are testimony to the effects of an arctic environment: specifically to the relatively low plant productivity of arctic areas and to the presence of frozen ground.

Slide 20

(Organic scarp, Mackenzie delta front)

52. Outer delta sediments are organic rich. This scarp at the front of the delta is largely organic in nature. But this richness is only relative. On deltas in more temperate climates, lakes are a very short-lived feature of delta plains. They are very quickly infilled by plant debris. This rapid infilling does not occur in the Arctic.
53. Frozen ground also plays an important role in lake formation and evolution. The most significant aspect of this role may be in the effect of freezing on the material consolidation or settlement of delta sediments under their own weight.
54. The argument I am about to make is pure speculation. It is not based on hard data but I will present it because of the implications it might have for development on the delta surface and for a pipeline across Shallow Bay.
55. A delta is not only a product of the balance between the river and the sea but also of the balance between river deposition and subsidence. On the Mississippi delta, buried deposits which were above sea level less than 500 years ago are now as much as 65 ft. below sea level, solely because of sediment consolidation under its own weight.

56. On the Mackenzie delta, however, the ground begins to freeze as areas are built up to near sea level. Natural consolidation will be stopped at the point in time at which the sediment freezes. If permafrost aggradation is rapid, the frozen sediments at depth will be under-consolidated with respect to the weight of the material over them. Added to this is the continuing addition of new weight in the form of deposition on top of the delta plain.
57. If this frozen ground is thawed for any reason, natural or otherwise, consolidation can begin again. On the outer delta plain, numerous lakes appear to have formed in areas of low-centred ice-wedge polygons, possibly because of water ponding, subsequent permafrost degradation and consolidation.
58. The bottoms of most lakes on the outer delta are above sea level at the present time. But in the Aklavik area, a much older and higher part of the delta; lakes whose bottoms are below present sea level have been reported. That this could occur in spite of infilling during river floods and deposition of organic debris may indicate continuing consolidation of the unfrozen sediments beneath the lakes.
59. Even in the absence of excess ice, then, - and there is little in the sediments of the outer delta plain - thaw consolidation remains an important problem. I am curious, as well, as to what effect natural consolidation might have on a pipeline across Shallow Bay - an area which, because of the presence of frozen ground at depth beneath it, may be a subsiding older part of the Mackenzie delta plain. If the rates are in the range of those found in the Mississippi, and I would guess they will be much lower, consolidation of anywhere from 1.5 to 4 ft. could occur over a 30 - year period.
60. Elsewhere along the Beaufort Sea coast, deltas occupy only a small proportion of the coastal zone. There are none at all on the Tuk Peninsula, although the Peninsula, itself, is composed largely of material deposited in an old Mackenzie delta. delta.

Slide 21

(Blow River delta plain)

61. Along the Yukon coast, the deltas of the Blow and Babbage rivers are similar in

-13-

form and sediment composition to the Mackenzie but are much smaller: the Blow delta plain covers only 31 sq. mi. and the Babbage 15 sq. mi. This slide looks north over the Blow delta plain toward the Beaufort Sea.

Slide 22

(Babbage delta during flood)

62. Unlike the Mackenzie, however, both delta plains can be covered in their entirety by storm surges. This view of the Babbage delta during spring river flooding could be repeated at any time during the summer by a major storm surge.

Slide 23

(Firth River fan delta)

63. The relatively steep, gravelly fan deltas of the Firth and Malcolm rivers, on the other hand, do not flood significantly during storm surges and thus are not as vulnerable to the effects of an oil spill. They also do not contain the low, fine-grained, frozen alluvial flats I mentioned earlier and would not be subject to significant thaw consolidation. This view of the Firth delta shows the aufeis deposits already much discussed in these hearings. Possible borrow pit operations on these deltas have also been covered in earlier testimony.

Coastal Change

64. I have left until the end any detailed discussion of the nature and rates of change of the landforms of the Beaufort Sea coast because I consider coastal stability to be the single most important factor in relation to possible development activities.
65. Under the influence of wave action, particularly during storm surges, the coastal cliffs within each coastal segment I have identified are being cut back and the material moved along shore and deposited, either in the form of spits and bars in the case of coarse sediment or offshore in the case of

finer sediment. The coastline is thus a very dynamic environment and, if the design of onshore installations or pipelines from offshore does not take this into account, they will eventually fail.

66. Cliff retreat is most rapid where offshore gradients are steep and where cliff sediments contain considerable pore, wedge or massive ice.

Slide 24

(Kay Point, undercut cliff)

Photogrammetric measurements show that this undercut bluff at Kay Point retreated almost 300 ft. between 1952 and 1970. Retreat of 25-150 ft. over the same period occurred along most of Babbage Bight, east of Kay Point. Other zones of rapid cliff retreat include the Herschel Island area, the old islands (Pelly, Hooper, etc.) which front the Mackenzie delta, and the Tuktoyaktuk settlement area.

67. The way in which retreat occurs is unique to an Arctic environment and is largely a function of features related to frozen ground. The headwalls of the ground ice slumps I showed you earlier are very rapidly receding: we have measured over 30 ft. of retreat in a single year on one.

Slide 25

(Block slumping near Kay Point)

68. Elsewhere, undercutting by waves and melting along ice wedge cracks can cause entire polygon blocks to collapse into the sea. This view was taken near Kay Point this past summer,

Slide 26

(Slumped polygon block, ice-wedge fracture)

and this is a close-up of the fracture zone at the back of the slumped blocks showing the exposed wedge ice.

69. The implications for development of these rates of retreat and of the way in which it occurs must be obvious. I should add only that the rates of retreat are not constant either seasonally or annually. Most retreat occurs during storm surges; 45 ft. of land was lost near the RCMP station of Tuk during the major 1970 storm,

almost one-quarter of the total retreat between 1950 and 1972.

70. It will be tempting to obtain sand and gravel for construction purposes from the coastal beaches, bars and spits where continued coarse sediment movement from cliff retreat promises rapidly replenished supplies of high quality aggregate. Spits have extended as much as 2300 ft. in length between 1952 and 1970 (Kunluk spit).
71. In addition to the biologic consequences that may make extraction of this gravel unsuitable, there are a number of things which should be known before permits to mine gravel are granted.
72. Material supplied to the beaches, bars and spits is in continuous movement along the shore. Extracting gravel will tend to accelerate nearby shore erosion, particularly in the downdrift direction, and the effects of this must be determined. For example, if sand were taken from the beaches north of Tuktoyaktuk the supply to the beach which fronts the townsite would be interrupted and the coastal cliff there would retreat even more rapidly than it already is. A permanently dredged deep channel into Tuk Harbour would have the same effect unless the dredged material was pumped out downdrift from the channel.
73. The sources of material in the beaches is primarily local in nature. Little coarse sediment will move between the coastal segments I have identified. In some segments, the spits and bars may be relic in nature and material, once removed, will not be replaced. For example, Avadiek spit on Herschel Island was formed from sands and gravels supplied by deposits on the north and west sides of the island, deposits which no longer exist because of cliff retreat.
74. The dynamic nature of beaches, spits and bars is also relevant to the effect oil from a spill might have on them. During the small August 1975 storm surge, the beach surface along the spit at Kay Point was cut down by as much as a foot and later reburied by almost the same amount of sand and gravel. Thus oil on these features could be buried at any time.
75. In direct contrast to the coastal cliffs and to the beaches, spits and bars, the delta plains of the Beaufort Sea coast, including that of the Mackenzie, are remarkably stable in nature.

76. Examination of aerial photograph sites spaced over a 22 year period revealed little shoreline advance along the front of the Mackenzie delta and no evidence of major channel shifts on the outer delta plain.

Slide 27

(Mackenzie delta shoreline)

In fact, as this slide of the delta shoreline shows, many areas have undergone minor retreat.

77. The rate of advance of a delta plain is dependent to a great extent on the balance between river and wave forces. Wave power at the shoreline, in turn, is dependent upon deep water wave conditions and the offshore gradient. Because the Beaufort Sea is frozen for much of the year and because the offshore gradient of the Mackenzie delta is one of the flattest of any major river delta in the world, we might expect that the total annual wave power exerted in the deltaic coastal zone would be very low in comparison with other major river deltas.
78. Under these conditions the Mackenzie delta should be advancing rapidly - but it is not. The only explanation must be that river power is also low and, now that the river has filled the protected trough between the Caribou Hills and the Richardson Mountains, it is not powerful enough to overcome the erosive wave energy of the open Beaufort Sea.
79. The lack of major channel shifting on the outer delta plain may also be related to low river power. This effect is accentuated by the number of channels which discharge into the Beaufort Sea - almost 60 with a total width of over 50 miles. This division of a given amount of river power leaves no single channel with enough to actively erode its banks.
80. This horizontal stability is, in itself, a simplifying factor for possible facilities associated with hydrocarbon development. From this point of view, only, construction which would be unfeasible on most other deltas in the world may be possible on the Mackenzie. There are, of course, other points of view, some of which I have discussed, which make the delta less attractive than horizontal stability considerations alone might suggest.

81. The last aspect of coastal change I wish to discuss is the direct effect of sea ice on the coastal zone and on the resultant need for careful selection of locations for the construction of nearshore facilities such as wharves and jetties. I think this can best be done with a slide and a question.

Slide 28

(Shoreline pressure ridge, Shingle Point spit)

Would you want to be a wharf or a jetty in the path of this 30 ft. high shoreline pressure ridge?

Conclusions

82. To briefly summarize and conclude, then:

- a. The coastal zone is, in most areas, a dynamic area, particularly so in this part of the Arctic, and its instability must be taken into account if it is to be used for pipelines, staging areas or other shore installations.
- b. Shore installations must be carefully located so as to avoid areas where large amounts of ground ice are present. Disturbance of the existing thermal regime will serve only to accelerate already rapid rates of coastal retreat.
- c. Beach material is primarily local in origin and its removal will lead to increased coastal erosion. As a general principle, therefore, I would recommend that beaches not be considered as sources of construction material.
- d. There are very few good harbour locations along the Beaufort Sea coast because of generally low offshore gradients, coastal instability and resultant longshore sediment movement.
- e. The hazards of liquid pollutant spills from shore operations could be minimized if these activities take place in bays or lagoons behind spits or barrier bars.
- f. Deltas are among the most complex active environments in the world because of the interaction between river and sea forces. The effects of an Arctic environment must be added to normal deltaic processes on the Mackenzie delta and these effects are not well understood. Because of this great complexity and because the Mackenzie delta is a unique North American environment, I would recommend that development on it be kept to a minimum.

- g. Oil from a spill reaching the nearshore in a given coastal segment will tend to remain in the segment and to move toward its sediment sink.
- h. The largest areas subject to frequent inundation by sea water and thus, potentially, by oil contained in that water are the river deltas, particularly the Mackenzie. Thermal disturbance through vegetation damage could lead to considerable thaw consolidation, even in the absence of excess ice. Other susceptible coastal features are beaches, spits and barriers and breached thermokarst lakes.

Charles Peter Lewis

Present position:

Physical Scientist with the Terrain Sciences Division, Geological Survey of Canada, Department of Energy, Mines and Resources.

Education:

B.A. Chemistry, physical geography; University of Waterloo, Waterloo, Ont.; 1961-66.

M.A., Ph.D. work in physical geography under Dr. J.R. Mackay; University of British Columbia, Vancouver, B.C.; 1966-72.

Relevant work experience:

From 1967 to 1971, I carried out a study of the geomorphic evolution of Mackenzie Delta plain lakes, with emphasis on lake sedimentation and the processes responsible for it.

During 1972, I worked on a study of modern river environment on the Yukon north slope and since then I have concentrated on coastal and deltaic environments, along the Tuk Peninsula in 1973 and along the Yukon-Beaufort Sea coast in 1974 and 1975.

My current work is on sedimentary processes in the Kay Point area, Y.T., specifically in the local coastal environments and on the Babbage River delta.

Documents and Reports used.

- Canada, Department of Public Works, 1971. Beaufort Sea storm, September 13-16, 1970. Investigation of effects in the Mackenzie Delta region. Unpublished internal report. 23 p.
- Canada, Department of Public Works, 1971. Herschel Island - feasibility of a marine terminal. Unpublished internal report. 141 p.
- Carson, J.M., J.A. Hunter and C.P. Lewis, 1975. Marine seismic refraction profiling Kay Point, Yukon Territory. Geological Survey of Canada, Paper 75-1, Part B: 9-12.
- Lewis, C.P. and D.L. Forbes, 1974. Sediments and sedimentary processes, Yukon Beaufort Sea coast. Environmental - Social Committee, Northern Pipelines, Task Force on Northern Oil Development, Government of Canada, Report No. 74-29. 40 p.
- Mackay, J.R., 1963. The Mackenzie Delta area, N.W.T. Department of Mines and Technical Surveys, Geographical Branch Memoir 8. 202 p.
- McDonald, B.C. and C.P. Lewis, 1973. Geomorphic and sedimentologic processes of rivers and coast, Yukon coastal plain. Environmental - Social Committee, Northern Pipelines, Task Force on Northern Oil Development, Government of Canada, Report No. 73-39. 245 p.
- Morgan, J.P., 1967. Ephemeral estuaries of the deltaic environment. In: Lauff, G.H. (Editor), Estuaries. American Association for the Advancement of Science, Pub. No. 83, Washington: 115-120.

